



National Aeronautics and Space Administration

UAS Contingency Management: The Effect of Different Procedures on ATC in Civil Airspace Operations

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Human Systems Integration (HSI)
UAS Integration into the NAS





Outline



- Background
- Method
- Results
- Discussion
- Limitations and Future Research



Background

- **Unmanned Aerial Systems (UAS) in the National Airspace System (NAS):**
 - Demand has skyrocketed for routine access to the NAS
 - Military, scientific, national security and emergency management applications have all called for easier admittance
 - Currently required to obtain Certificate of Authorization (COA), a time consuming, restrictive process
 - Also requires air traffic controllers (ATC) to block airspace, which can reduce airspace efficiency



Background

➤ Barriers to Integration:

- Lack of agreed upon minimum performance standards
 - A chief concern is contingency management
 - How will UAS deal with emergency events, such as the loss of the command and control link (i.e., lost link)?
 - How will procedures impact the rest of the system?
 - Standardized and predictable contingency management procedures are essential to integration



Background



➤ Current Behaviors:

- UAS response to contingency events are agreed upon within individual COAs with the FAA
 - UAS may:
 - Return to base
 - Continue to destination
 - Return to mission altitude



Background

➤ Purpose of Study:

- Examine the impact of existing UAS contingency management procedures on air traffic control (ATC)
 - How do current UAS behaviors impact a controller's ability to maintain a **safe** and **efficient** airspace?
 - How do the behaviors impact controller's self-reported workload?
- Hypothesis:
 - More sudden and/or sizable maneuvers would negatively impact ATC performance and workload
 - Smaller maneuvers would have less impact on surrounding traffic
 - Less immediate maneuvers would provide time for pilot to inform ATC



Method



➤ Contingency Behavior

- Four current contingency behaviors were modeled in this study
 - 3 behaviors for responding to lost link
 - 1 behavior for responding to severe loss in oil pressure
- Developed through:
 - Review of existing documentation
 - MQ-9 flight manual
 - Joint Unmanned Aircraft Systems CONOPS
 - Semi-structured interviews
 - 3 current UAS pilots from 2 different platforms



Method

➤ Contingency Behavior

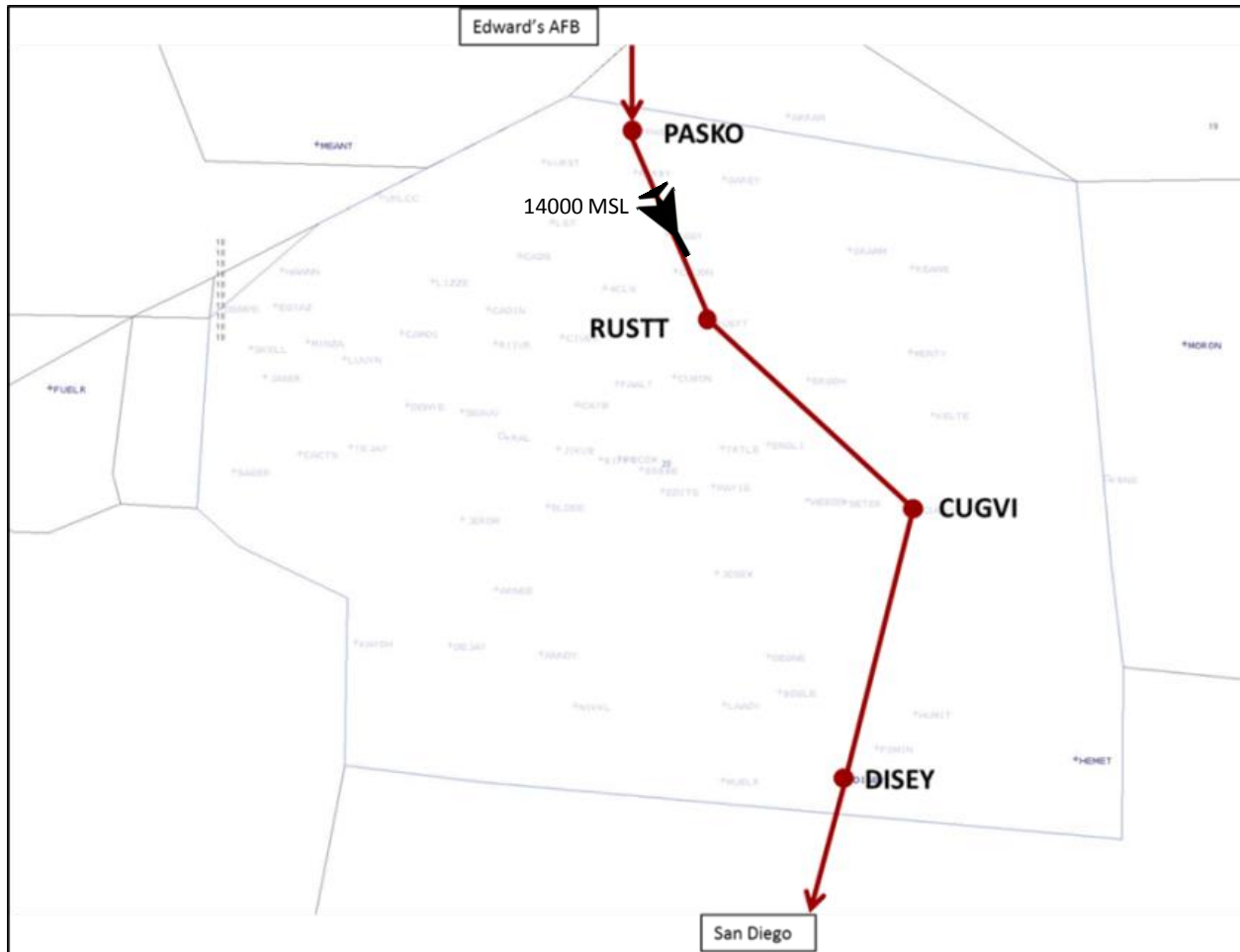
ID	Event	Contingency Behavior	Time to Execute
C1	N/A	N/A	N/A
C2	Lost Link	Return to Base (incl. 180° turn)	1 min
C3	Lost Link	Return to Base (incl. 180° turn)	8 min
C4	Lost Link	Maintain Course (Return to Mission Altitude)	1 min
C5	Drop in Oil Pressure	Land at Emergency Site (incl. descent of maximum 10000ft)	Immediate



Method



➤ C1: No Contingency Event

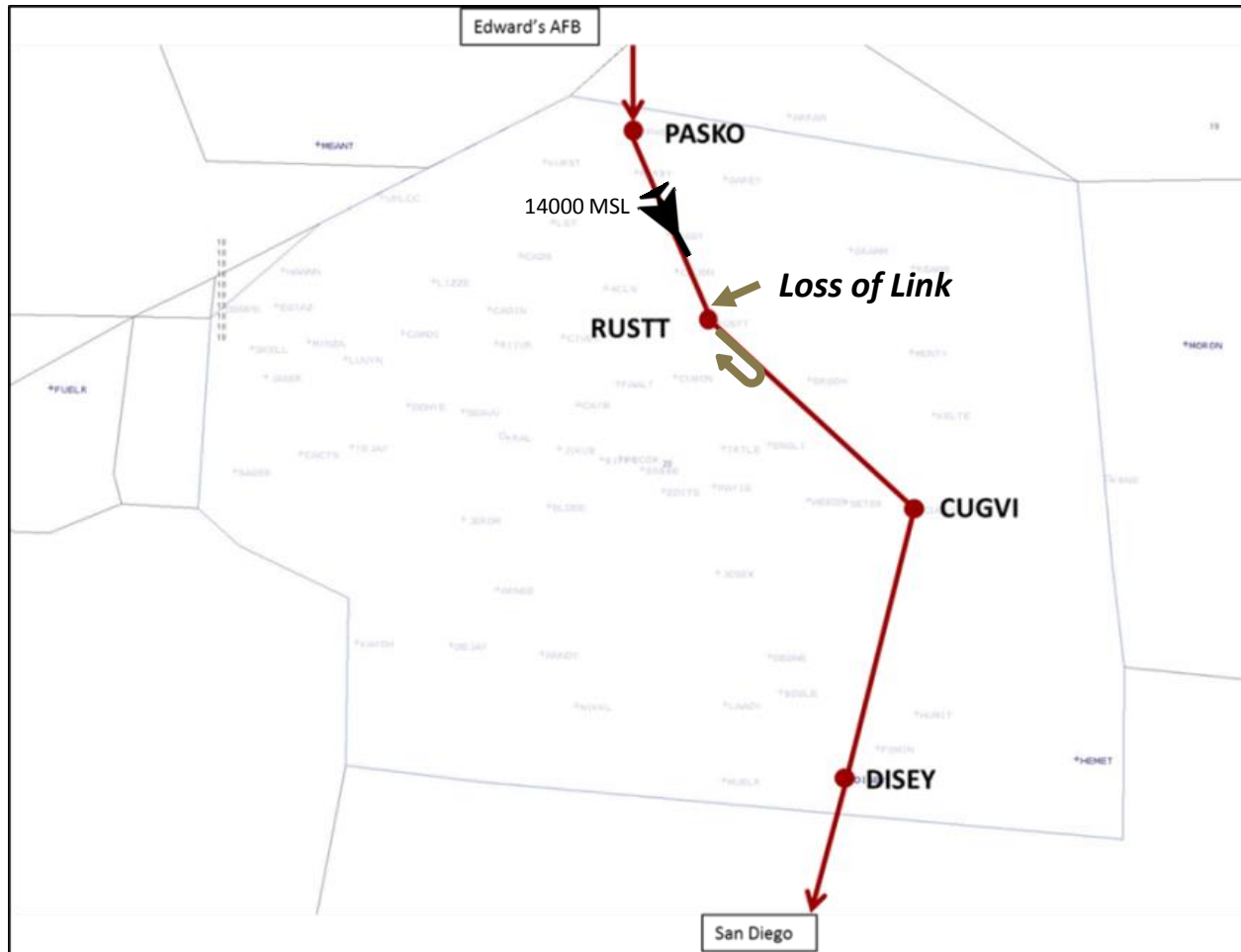




Method

➤ Contingency Behavior

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Method

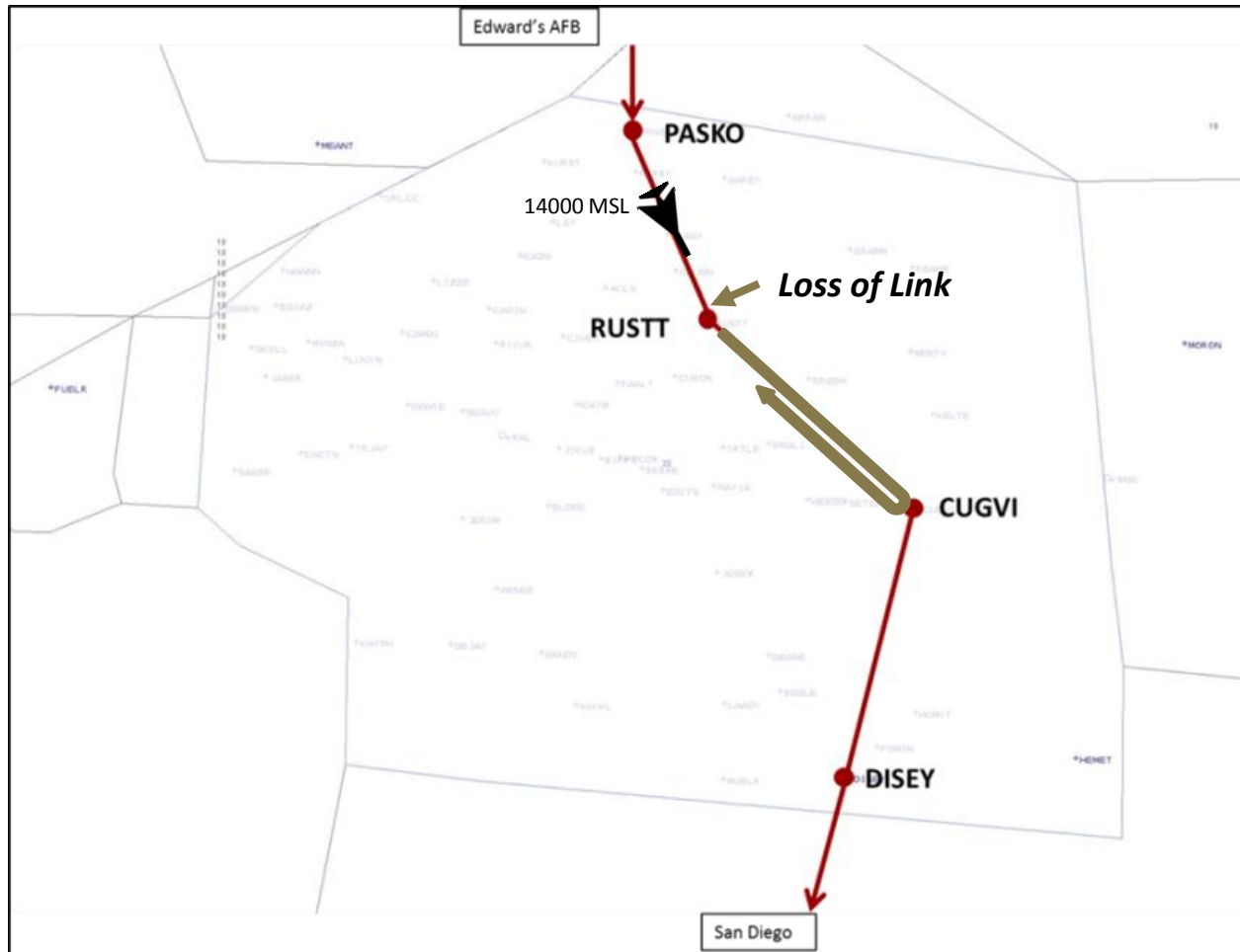
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C5	Drop in Oil Pressure	Land at Emergency Site (incl. descent of maximum 10000ft)	Immediate



Method

➤ C3: Return to Base in 8 Minutes





Method

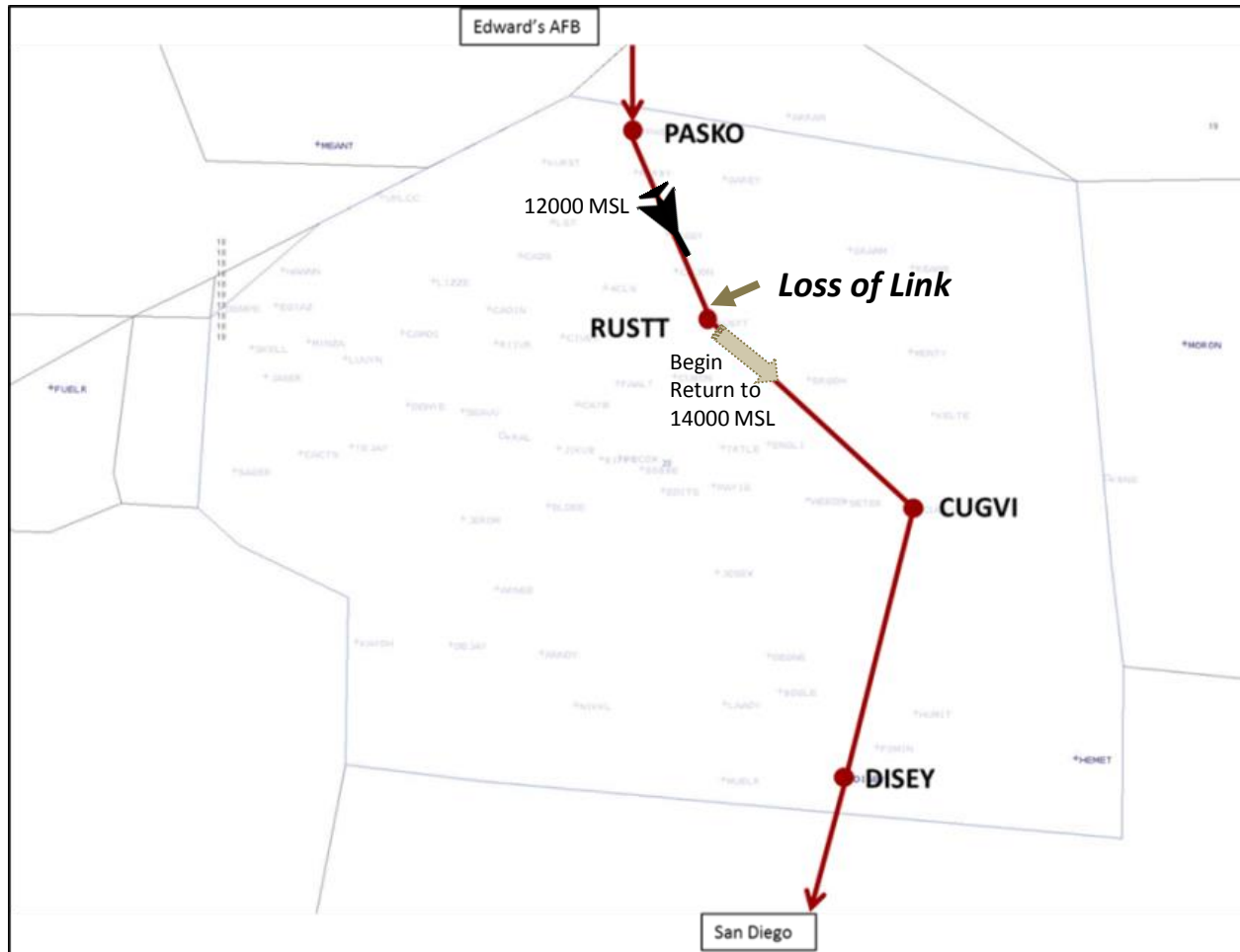
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C4	Lost Link	Maintain Course (Return to Mission Altitude)	1 min
C5	Drop in Oil Pressure	Land at Emergency Site (incl. descent of maximum 10000ft)	Immediate



Method

➤ C4: Maintain Course Return to Mission Alt





Method

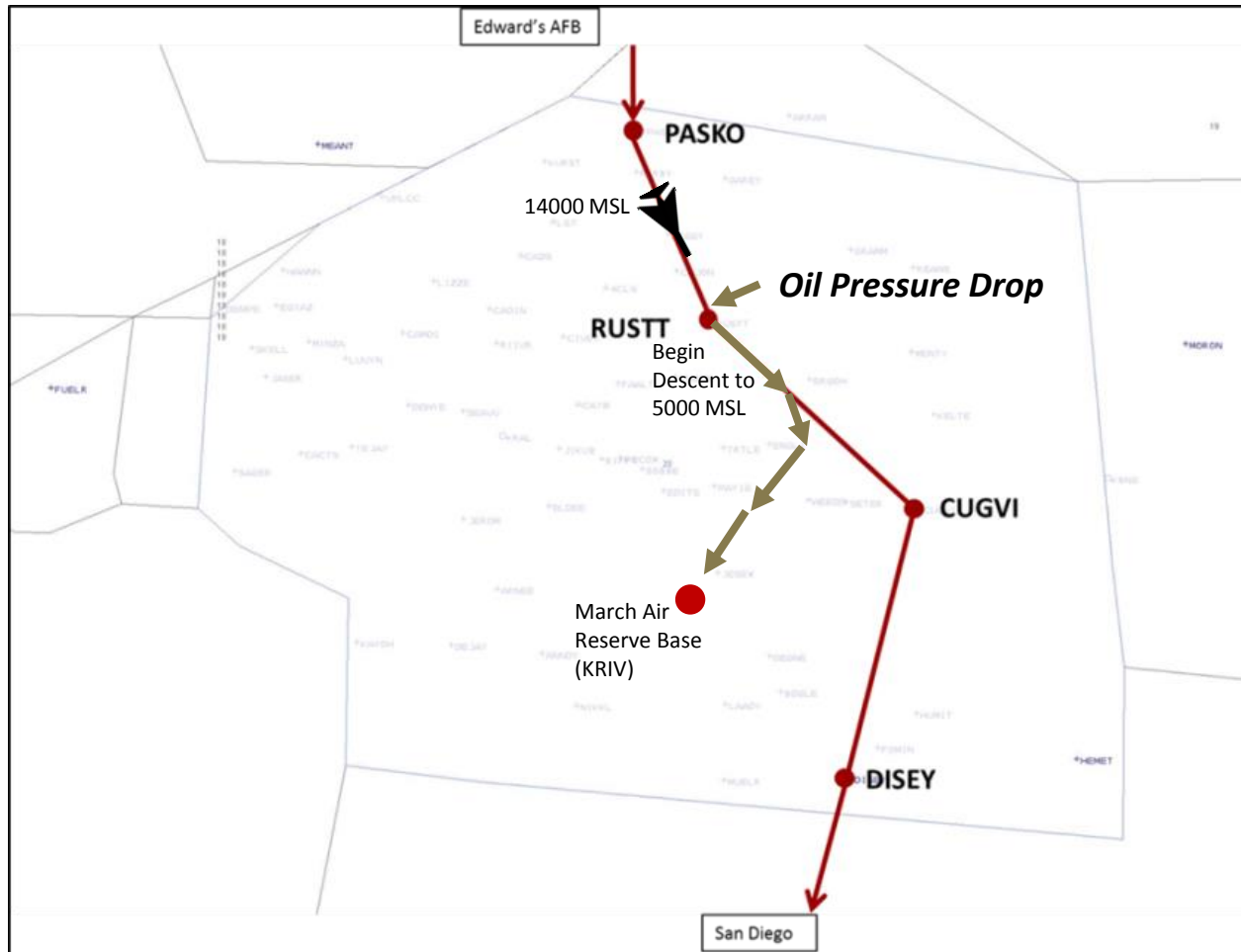
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C5	Drop in Oil Pressure	Land at Emergency Site (incl. descent of maximum 10000ft)	Immediate



Method

➤ C5: Emergency Landing at KRIV



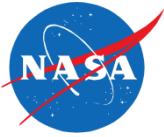


Method

➤ Contingency Behavior

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C4	Lost Link	Maintain Course (Return to Mission Altitude)	1 min
C5	Drop in Oil Pressure	Land at Emergency Site (incl. descent of maximum 10000ft)	Immediate

- Hypothesize that C3 and C4 will be least impactful on ATC performance
 - C2 and C5 most impactful



Method



➤ Experimental Design

- One-Way Repeated Measures Factorial
 - Contingency Behavior (5 levels, within subjects)
 - Counterbalanced order of presentation within each block across participants
 - Block (2 levels; within subjects)
 - No systematic difference between levels
- Experimental Scenarios
 - 2 Blocks
 - 5 experimental runs per block
 - Experimental runs lasted 17 min
 - Each trial followed up by workload and general questionnaire



Method



➤ Participants

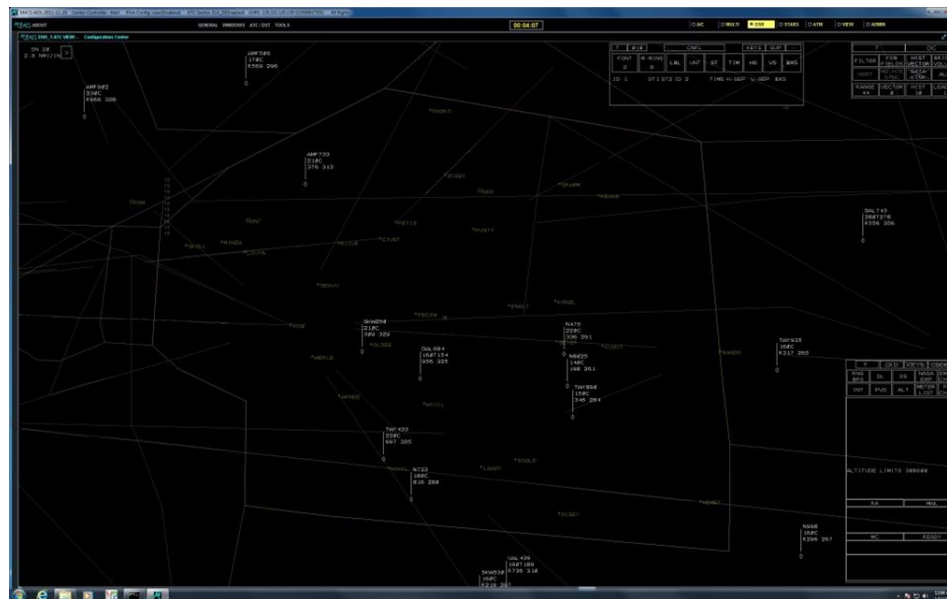
- 14 Retired Controllers (Male):
 - Civilian ATC Experience:
 - TRACON – 14/14 (26 years on avg.)
 - 13/14 had experience working East Feeder
 - Tower – 10/14
 - Center – 2/14
 - Military ATC Experience:
 - TRACON – 5/14
 - Tower – 4/14



Method

➤ Apparatus

- Multi Aircraft Control System (MACS) provided controller display
- Display System Replacement (DSR) presentation of Southern California TRACON [East Feeder/ZLA20]
 - Hybrid sector – airspace positively controlled from surface to FL230
 - Participants used keyboard and mouse for inputs



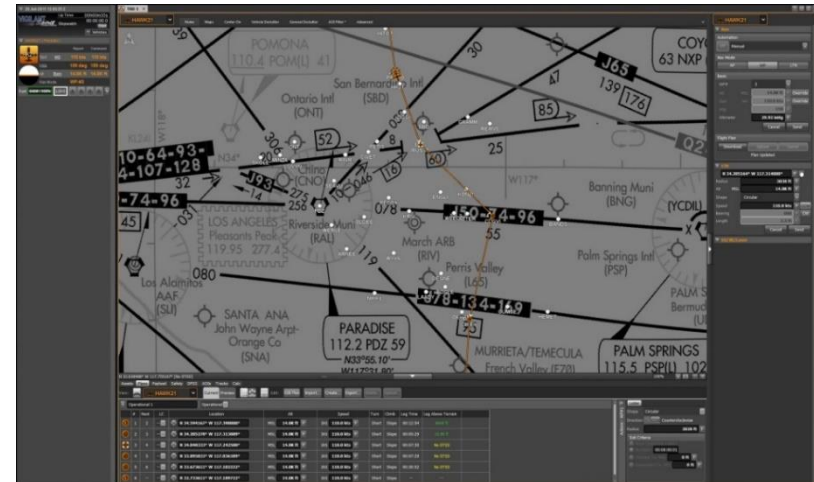


Method



➤ Apparatus

- Vigilant Spirit Control Station (VSCS) provided simulated UAS ground control station
 - Allowed for simulated injection events (e.g., loss link and severe oil loss)
 - UAS pilot provided with script when coordinating with ATC following contingencies
 - MQ1 Predator (Modified)
 - Speed: 110 knots
 - Mission Alt: 14000 MSL



-Vigilant Spirit Control System, AFRL-

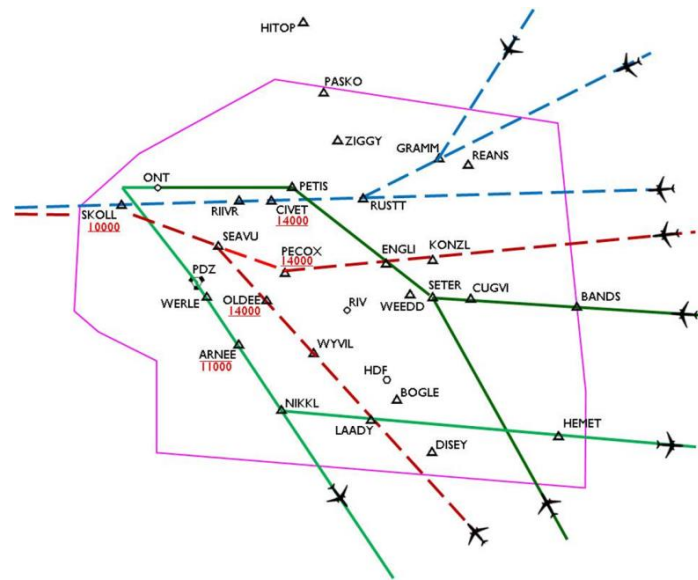


Method



➤ Apparatus

- Traffic Scenarios
 - Designed off of a busy, current day at SoCal TRACON
 - Included arrivals into LAX and ONT, as well as overflights (in addition to single UAS)
 - Manned aircraft were level when entering sector
 - Arrivals had to be manually descended by ATC



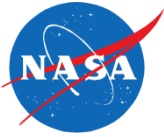


Method



➤ Procedure

- Task:
 - Maintain safe separation
 - 3nm and 1000ft (approach airspace separation requirements)
 - Ensure LAX arrivals meet appropriate altitude restrictions.
 - LAX arrivals required to exit sector @SKOLL at 10000 MSL
 - Descent ONT arrivals to 5000 MSL for visual approach
 - No coordination with ONT tower
 - Manage overflights (including UAS)
- Training
 - Trained on MACS software and overall sector operations
 - Included brief on UAS characteristics and potential contingencies
 - 3 practice scenarios (2 with only manned AC, 1 with UAS)
 - No practice on UAS contingency behaviors



Method

➤ Metrics

- *ATC Performance*
 - Safety
 - Number of Losses of Separation (violation of 3nm and 1000ft)
 - Workload
 - Handoff Accept Time
 - Time elapsed between adjacent sector's initial handoff and experimental controller's acceptance)
 - Efficiency
 - Avg. time in sector per AC
 - Avg. distance flown per AC
- *Subjective Ratings*
 - NASA-Task Load Index
 - Mental Demand, Physical Demand, Temporal Demand, Performance Degradation, Effort and Frustration
 - Post-Trial Questionnaire
 - Assessed impact of contingencies on controller's self reported separation strategies
 - Post-Simulation Questionnaire
 - Queried controllers on overall simulation fidelity and compared across levels of Contingency Behavior

➤ Analysis

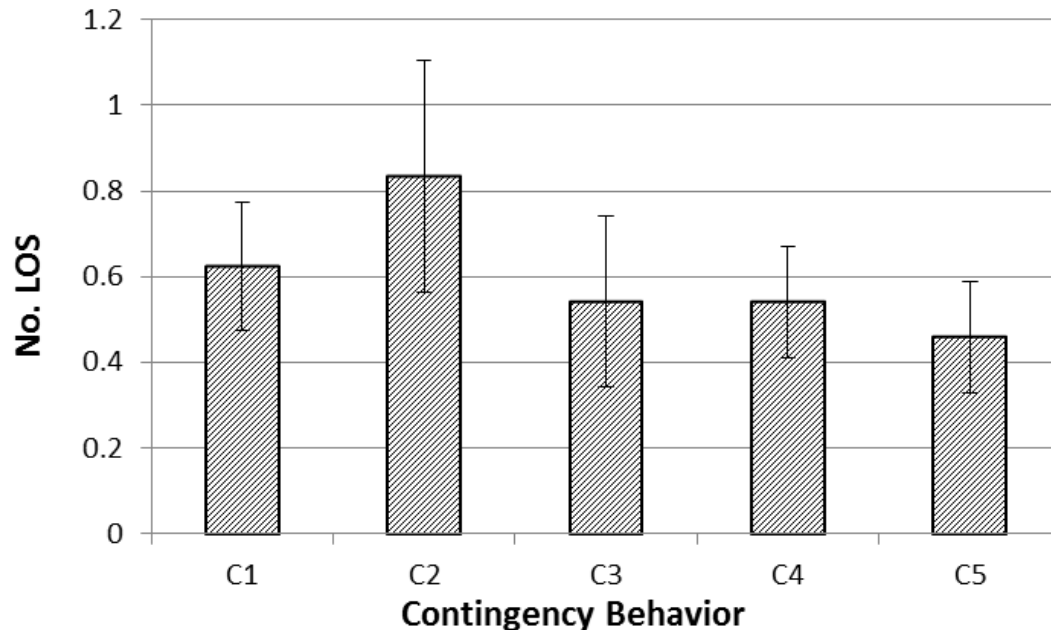
- Data analyzed using a 5 (Contingency Behavior: C1-C5) x 2 (Block: 1-2) Repeated Measures ANOVA



Results: ATC Performance

➤ Safety

- No significant main effect of Contingency Behavior on Number of LOS ($p>.05$)
 - LOS were low across all levels of Contingency Behavior



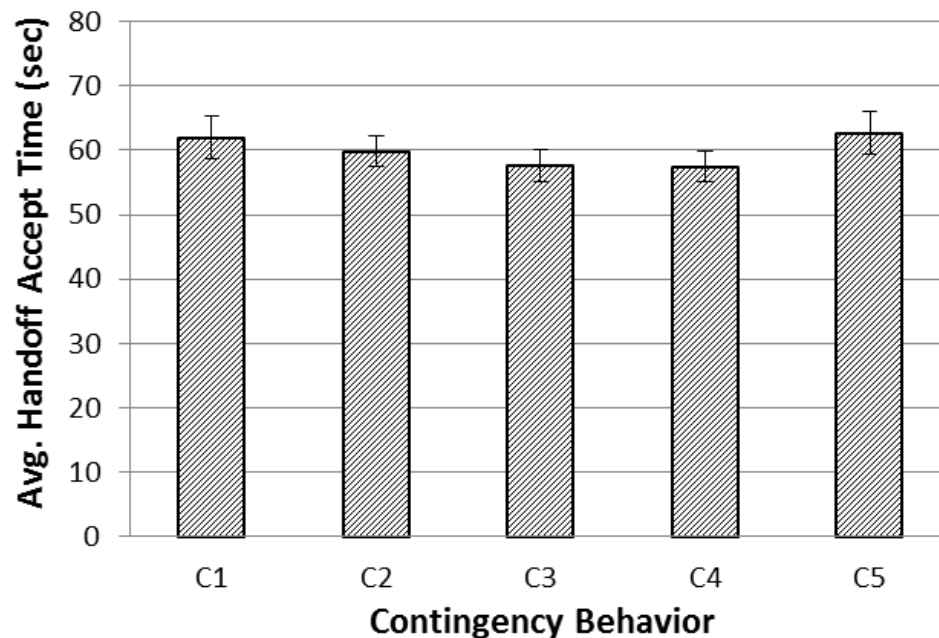
Label	Description
C1	No contingency (baseline)
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C4	Maintain course (return to alt)
C5	Emergency landing



Results: ATC Performance

➤ Workload

- No significant main effect of Contingency Behavior on number of handoff accept time ($p > .05$)
 - Handoff accept times were low and stable across conditions



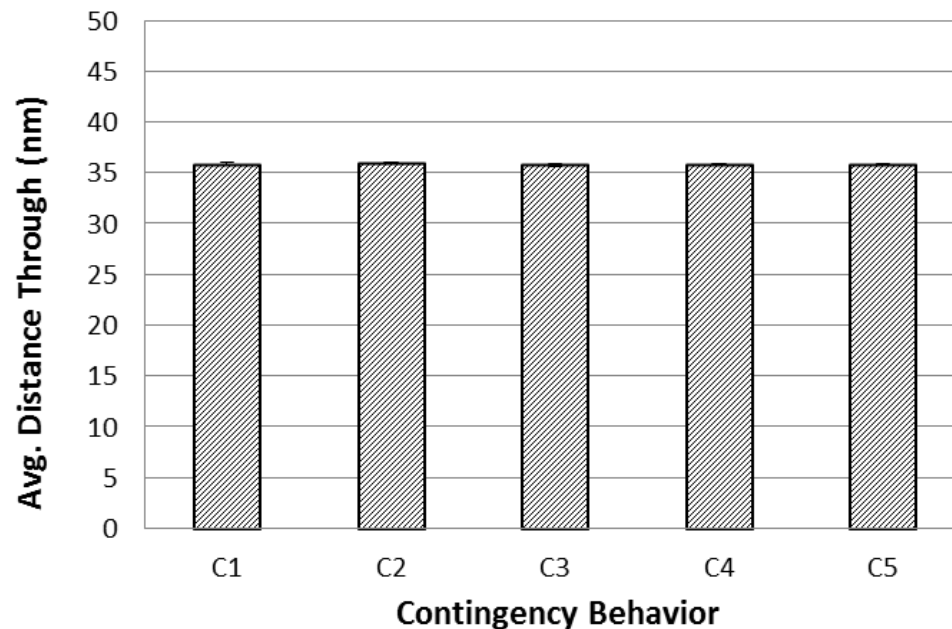
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C5	Emergency landing



Results: ATC Performance

➤ Efficiency

- No significant main effect of Contingency Behavior on Distance Through Sector ($p > .05$)
 - Controllers remarkably consistent between conditions



Label	Description
C1	No contingency (baseline)
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C4	Maintain course (return to alt)
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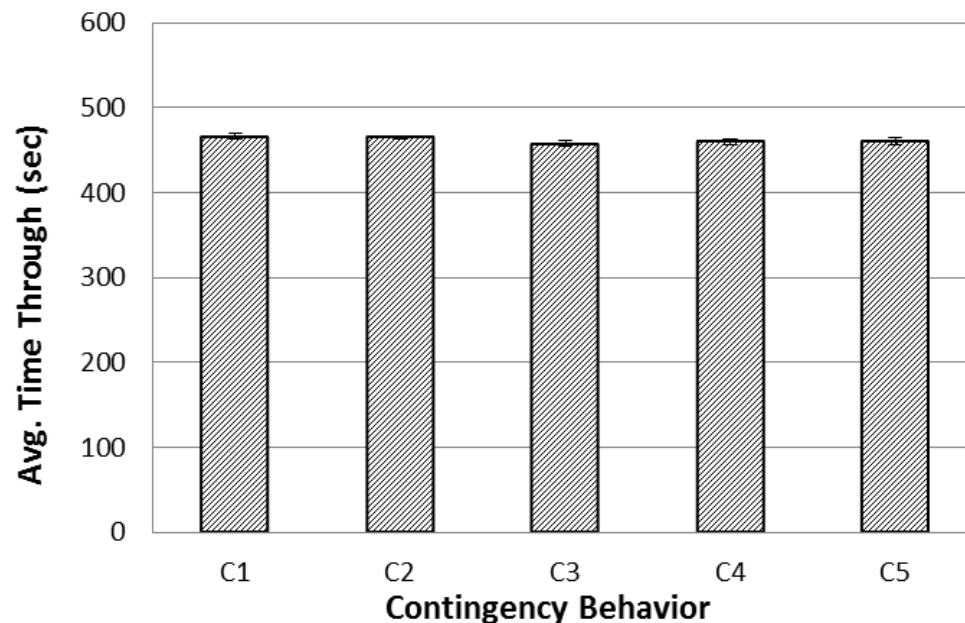


Results: ATC Performance

➤ Efficiency

- No significant main effect of Contingency Behavior on Time Through Sector ($p > .05$)
 - Controllers consistent across conditions

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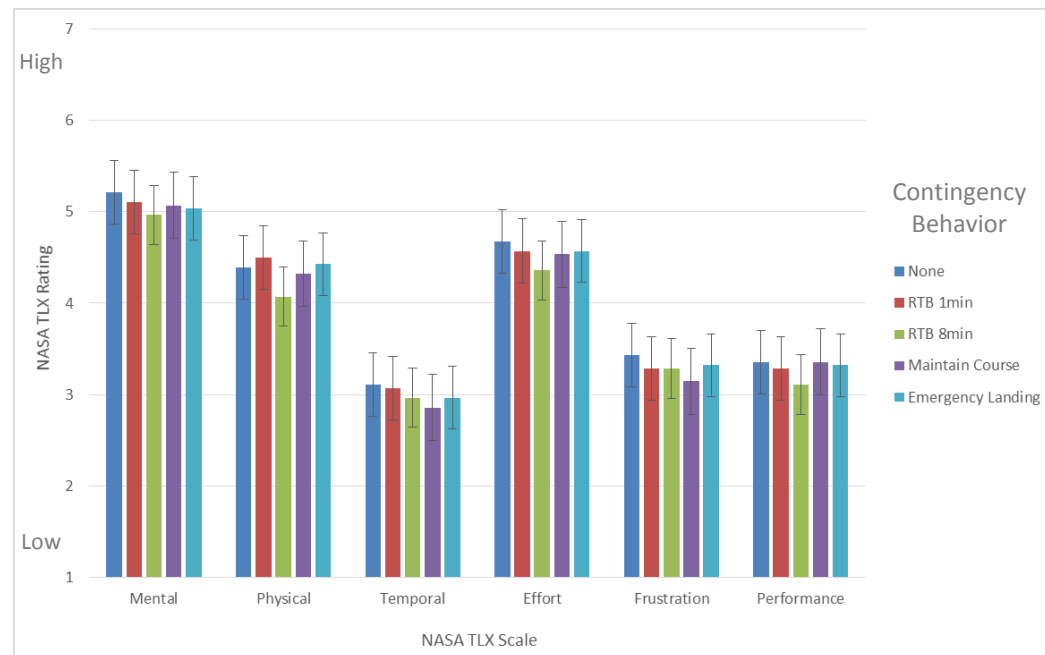


Results: Subjective Ratings

➤ NASA-TLX

- No significant main effect of Contingency Behavior on any of controller's self-reported workload scales (p 's>.05)
 - Mental, Physical and Effort demands slightly above average
 - Temporal, Frustration and Performance demands slightly below

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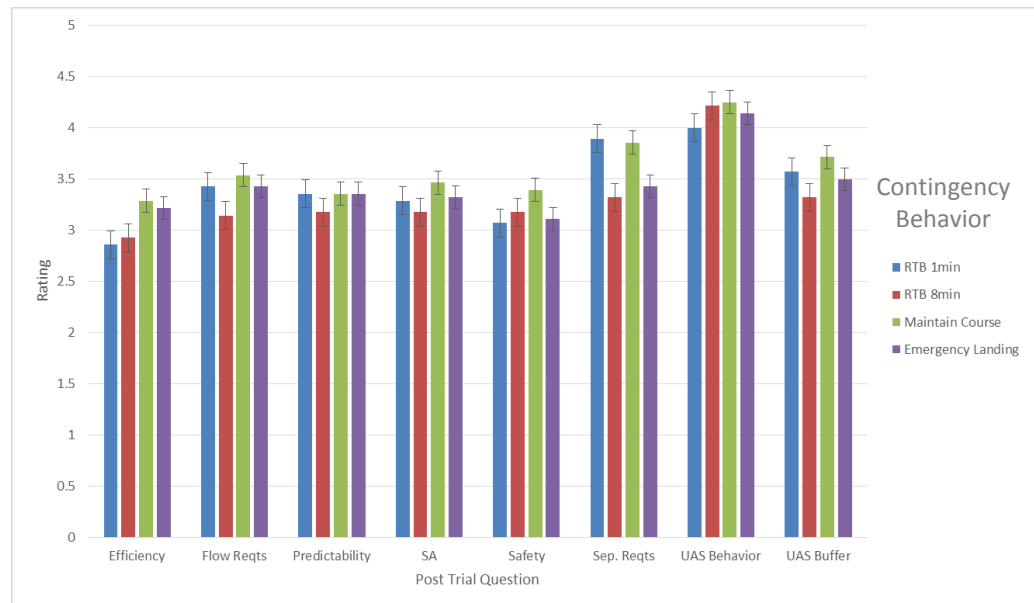


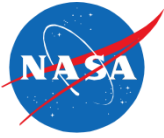
Results: Subjective Ratings

➤ Post-Trial Questionnaire

- No significant effect on any of the 8 questions (p 's > .05)
 - Rating: 0 (Strongly Disagree) – 5 (Strongly Agree)
- Questions included:
 - Impact on ability to safely/efficiently manage sector
 - Impact on situation awareness
 - Predictability of behavior
 - Buffer size for UAS

Label	Description
C1	No contingency (baseline)
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C3	Return to base (8 minutes)
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C5	Emergency landing





Results: Subjective Ratings

➤ Post-Simulation Questionnaire

- Controller's were asked their preferred contingency behavior (from *Most Impactful* to *Least Impactful*) in terms of:
 - Safety
 - Efficiency
 - Workload
- For all 3 questions controllers responded:
 - C4 (Return to Mission Alt/Maintain Pre-Programmed Course)
 - C3 (Return to Base in 8min)
 - C2 (Return to Base in 1min)
 - C1 (Emergency Landing)



Conclusion

➤ Study suggests:

- Contrary to hypothesis, current contingencies found to have no positive or negative effects on controller performance or subjective reports
- No differences between contingencies or relative to baseline condition (with no contingency event)
 - Losses of separation, handoff accept times, time and distance through sector saw no significant effects
 - Workload, post trial and post simulation questionnaires also failed to see effects
- However, when asked, controllers found the Return to Altitude/Maintain Course & the 8 minute Return to Base contingencies to be the least impactful
 - Emergency landing contingency was rated as most impactful



Conclusion

➤ Explanation of findings

- Controllers commented that dealing with a single UAS (even when operating under a variety of contingency procedures) was not problematic
 - Nearly all controllers noted that they frequently dealt with “special” AC while working ZLA20 (East Feeder)
 - DEA and FBI routinely flew helicopters or fixed-wing AC at low altitudes with unpredictable routing
 - Participants had worked East Feeder, likely very motivated/talented controllers
- Suggests controllers’ skill sets were robust enough to accommodate a single, unpredictable, slow-moving AC
- FAA likely designs contingency procedures that are *intentionally* minimally impactful



Conclusion

➤ Limitations:

- No “true” baseline scenario – i.e., trial without UAS present
 - May have obscured comparisons
- Looked only at approach airspace that was relatively conflict free
 - Used a hybrid sector (part approach, part center) with traffic that was flying level
 - Class A (no VFR included in scenario)



Conclusion

➤ **Recommendations for Future Research:**

- Present the contingencies within more difficult contexts
 - Higher density traffic
 - Different airspace (e.g., Class E or D)
 - Script complex conflicts with the UA
- Simulate different types of contingencies
 - Context-sensitive contingencies
 - UAS behavior is dictated by the current airspace or operation
 - Design purposefully disruptive contingencies to demonstrate sensitivity of our metrics
 - May make it easier to accept null hypothesis
- NORTHCOMM is currently testing impact of contingency operations in flight test conditions



Conclusion



➤ **Questions?**